Lasers in Surgery and Medicine 26:33–40 (2000)

Influence of the Anagen:Telogen Ratio on Q-Switched Nd:YAG Laser Hair Removal Efficacy

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Background and Objective: **Laser hair removal is believed to affect only anagen hairs. However, proof of this belief in humans is lacking. The objective of this study was to determine the influence of the anagen: telogen ratio on the results of Q-switched Nd:YAG laser hair removal.**
Study Design/Materials and Methods: **Fifteen subjects had four test sites delineated in one body area. The test sites were chosen by trimming the hair and evaluating the area in 2 weeks. At that time, the anagen hairs were at least twice as long as the nongrowing telogen hairs and, therefore, could be differentiated and counted. Two sites with a low anagen number and two with a high number were chosen for comparison. All sites were then treated with a Q-switched Nd:YAG laser. Follow-up examination was in 1 month.**
Results: **Test sites with a low anagen number demonstrated a low level of hair loss compared with those sites with a high anagen number. A significantly higher percentage of hair loss was noted when comparing the anagen-only with total hair loss. In addition, lasing plus shaving demonstrated more hair loss than lasing alone. These findings indicated that anagen hairs were clearly affected, but the immediate clinical effect on telogen hairs was minimal.**
Conclusion: **Q-switched Nd:YAG laser treatment of anagen hairs results in a rapid switch to telogen and a subsequent clinically obvious shedding of the hair shaft. This process causes a greater percentage hair loss at sites with high anagen number. Telogen hairs demonstrate no such effect and remain in their pretreatment phase after lasing. Lasers Surg. Med. 26:33–40, 2000.** **© 2000 Wiley-Liss, Inc.**

Key words: anagen:telogen ratio; Q-switched; Nd-YAG; laser hair removal; phototrichogram

INTRODUCTION

The use of lasers and intense pulsed light sources to induce follicular damage is rapidly increasing. Optimal parameters for best results are continually being revised. One of these treatment parameters involves the phase of the hair cycle most responsive to treatment.

It has been suggested that only anagen hairs respond to laser or intense incoherent light pulses [1–3]. This is thought to be at least in part because anagen hair bulbs contain the highest concentration of melanin. Melanogenesis ceases during catagen, reducing the pigmentation of the subsequent telogen-stage hair bulbs. Without a target of concentrated follicular melanin, it is hypothesized that laser pulses lose much of their efficacy on hair follicles in telogen. It has also been suggested that actively growing anagen follicular cells may be more sensitive to laser insult than are nongrowing telogen cells.

Some microscopic observations support the idea of greater anagen susceptibility as well. Follicles from 11 subjects were examined histologically before and 1, 2, and 4 months after treatment with a Q-switched Nd:YAG laser [4]. Most

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Accepted 8 September 1999

laser-induced effects were noted in anagen hair bulbs with only mild damage seen in but a few telogen follicles. In addition, this hypothesis may be partly rooted in the electrology literature because electrologists have long stated that only anagen hairs respond to their treatment [5]. Nonetheless, we are unaware of clinical experimental data that support this observation.

One animal study has been conducted that corroborates the idea that anagen is the stage most responsive to laser hair removal [3]. However, no human studies have been found that prove this to be true. This study was designed to address the question of the optimal human hair cycle stage for Q-switched laser hair removal.

MATERIALS AND METHODS

Q-Switched Nd:YAG Laser Study

Fifteen subjects were enrolled in this study. Criteria for inclusion were an age of 18 years or older, good general health, and a commitment to use no other hair removal methods during the study. Subjects with hair that could be easily identified photographically were chosen. The sites to be treated had never been previously treated with a laser, nor had they been waxed within the 4 weeks before treatment. Skin types I-IV were represented in this study. Hair color varied from brown to black.

At the first visit, informed consent and demographic information was obtained. No treatment was done. Several areas from the same body region in each subject were identified for possible treatment. All hairs were then trimmed to approximately 1–2 mm.

Subjects were seen again in 2 weeks. After evaluating the potential test regions, many high vs. low anagen:telogen sites were evident on clinical examination. Telogen hairs could be identified as those that had not grown in the ensuing 2 weeks. Anagen hairs had clearly extended by several millimeters (Fig. 1). From the available sites, four areas from the same body region were chosen at random for treatment, two with a high anagen number and two with a low number for a total of 60 sites in the 15 subjects. After site selection, a template was made out of plastic sheeting, which incorporated surrounding landmarks and their relation to the treatment areas. Photographs were then taken with a high-resolution digital camera (Kodak Professional DCS 420, Eastman Kodak Company, Rochester, NY) and treatment was performed.

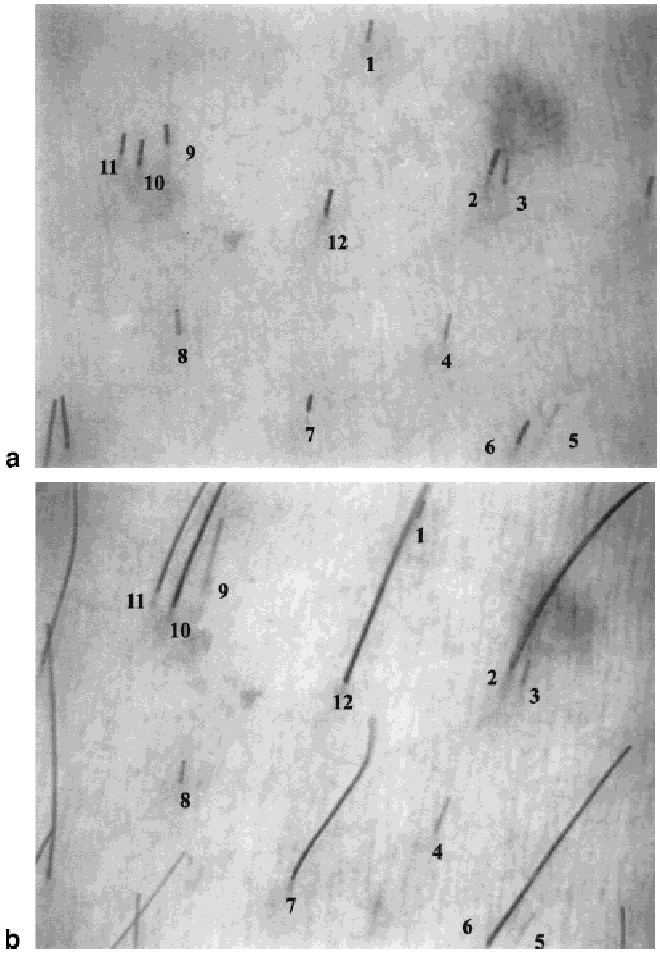

Fig. 1. Phototrichograms of individually tracked follicles taken at baseline (**A**) and 2 weeks (**B**). Note the growth of anagen hairs (hair numbers 2, 6, 7, and 10–12) at the 2-week follow-up period and the static nature of those hairs in telogen (hair numbers 1, 3–5, 8, and 9). Hair number 9 apparently entered telogen soon after the baseline phototrichogram as evidenced by its slight lengthening at 2 weeks.

Treatment was done with a Q-switched Nd:YAG laser (SoftLight, ThermoLase Corporation, San Diego, CA) in conjunction with a topical carbon suspension as previously described [4,6–8]. Briefly, a topical carbon-based suspension was applied to the skin surface and allowed to absorb for several minutes; the excess was removed. The laser was used at 1,064 nm, a pulse repetition rate of 10 Hz, a pulse duration of 17 nanoseconds, and a fluence of 2.5 J/cm^2 in a 7-mm beam. Four passes were made over the entire test site and consisted of horizontal, vertical, diagonal, and 90° to diagonal passes. Test site hairs were trimmed to a length of 1–2 mm immediately before treatment.

Four to 5 weeks after treatment, all subjects

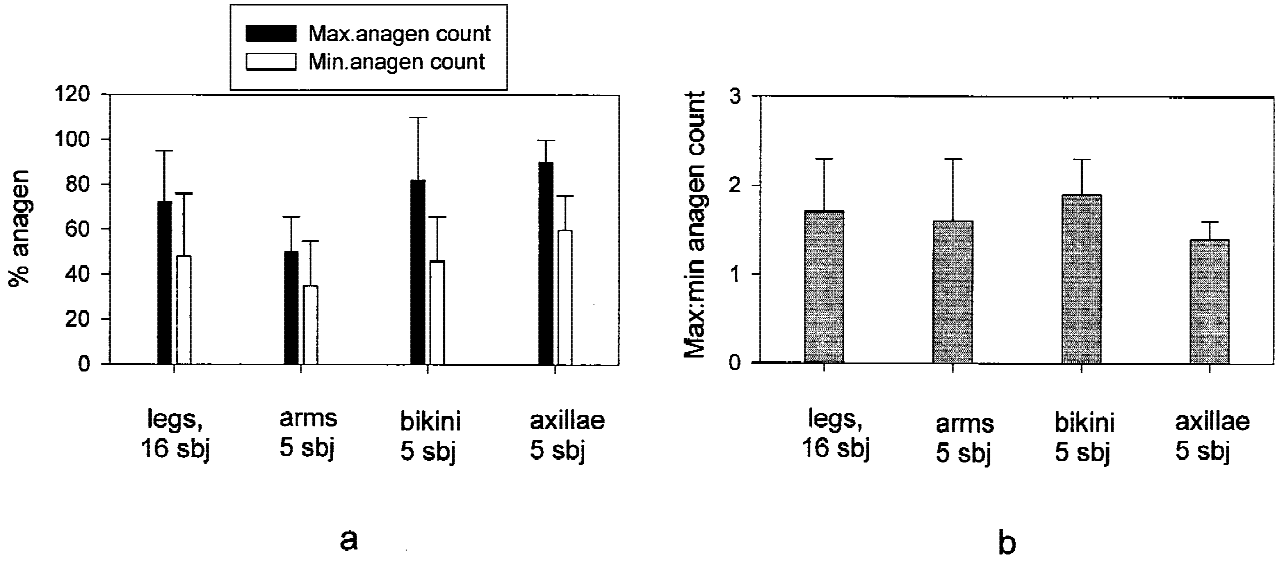

Fig. 2. Graphs representing the high and low anagen numbers in four body sites. The maximum and minimum anagen counts are seen in (**a**) and the maximum to minimum anagen ratios are depicted in (**b**). These graphs include data from other study subjects in addition to the 15 in this study. sbj, subject.

were assessed. The treatment areas were again marked and photographed. All visible test site hairs were counted manually and photographically. Hair reduction percentages were then determined.

Statistical significance for the differences in hair reduction between low and high anagen:telogen ratio sites was verified by using the Wilcoxon signed-rank test. Two nonoverlapping samples, each containing 15 data points, were selected for comparison from the total of 60 data points in the study. The data selected for the first sample represented the lowest pretreatment anagen:telogen ratios (0.49 ± 0.23). The data included in the second sample had the highest pretreatment anagen:telogen ratios (3.03 ± 1.55).

Individual Follicle Growth Kinetics

Individual follicles were closely followed over time in one subject to acquire information on hair growth kinetics with and without Q-switched Nd:YAG laser treatment. Two sites with 12 and 13 hairs were chosen. A template was made of the sites followed by phototrichograms (Cosmax-200 video camera, Medicom Systems, Wheeling, IL, Fig. 1). The hairs were given numbers for subsequent identification. One site was treated with the Q-switched Nd:YAG laser as described above. The other site had no treatment and served as a control. Sites were examined and phototrichograms were taken every 2 weeks for at least 12 weeks.

RESULTS

Experimental data are summarized in Figures 2–7.

Q-Switched Nd:YAG Laser Study

Anagen hair percentages were evaluated in potential test sites of all subjects at the baseline and pretreatment visits. Sixteen additional data points were obtained from other study subjects in whom anagen percentages had been determined in an identical manner. Two sites with maximal and two with minimal anagen percentages were chosen to characterize variations in the anagen density of various body areas. The values of maximum to minimum anagen percentages can be seen in Figure 2a. The maximum percentage was clearly much higher than the minimum. The ratio of maximum to minimum hair counts was approximately 1.5–2 in all body areas (Fig. 2b).

Figure 3a shows the total hair reduction 4–5 weeks after treatment. Sites with a low pretreatment anagen:telogen ratio had a lower percentage hair loss than those with a high ratio. If only anagen hairs are counted (Fig. 3b), it is clear that the anagen hair loss is greater than the total at all pretreatment ratios. The difference between these two graphs (Fig. 3a vs. 3b) represents persistent telogen hairs.

The effect of lasing alone was compared with that of lasing plus shaving (Fig. 4). If no shaving is done, both anagen and nongrowing telogen

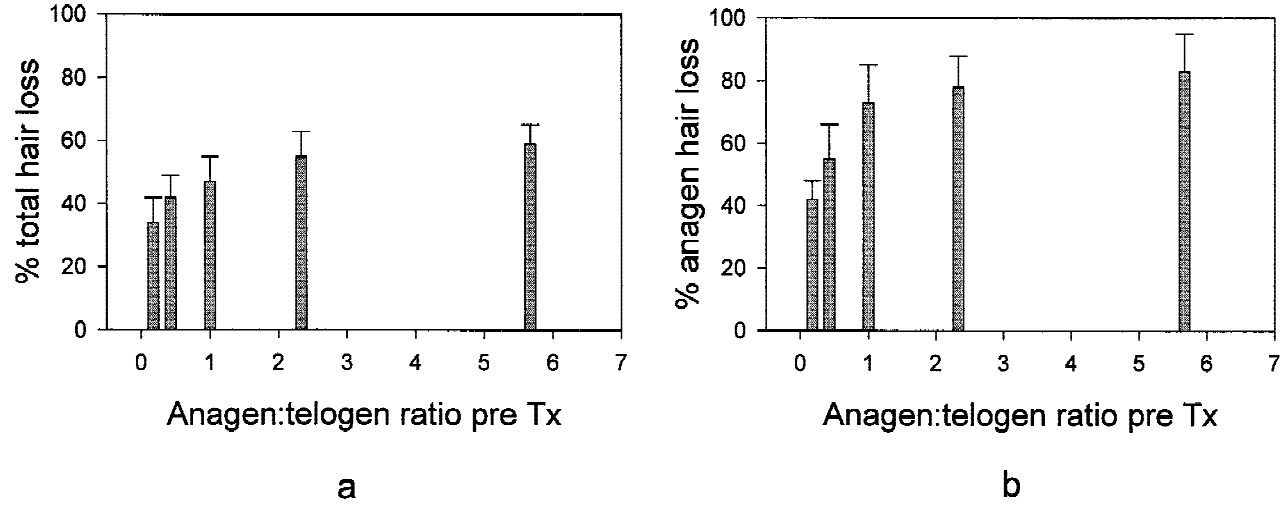

Fig. 3. Hair reduction as a function of the pretreatment anagen:telogen ratio 4–5 weeks postoperatively. (**a**) the total hair reduction (**b**) the anagen hair reduction. Hair loss is directly related to the pretreatment anagen:telogen ratio. Note the difference in reduction at all ratios when considering total (a) versus anagen (b) hairs. Tx, treatment.

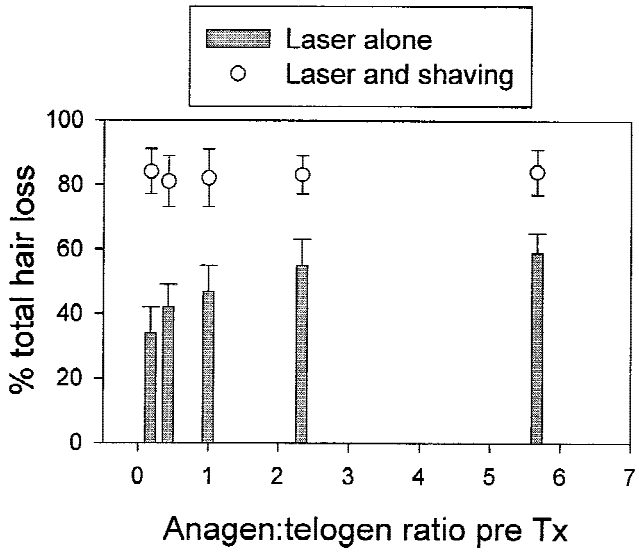

Fig. 4. The total hair loss of lasing alone compared with lasing plus shaving. Note the apparent improvement of hair loss regardless of the anagen:telogen ratio in the lasing plus shaving sites.

hairs are counted. If shaving is added to the treatment, nongrowing telogen hairs are invisible and only anagen hairs can be counted. As Figure 4 demonstrates, lasing plus shaving resulted in an at least 80% apparent hair removal without regard to the anagen:telogen ratio. The apparent improvement in hair loss is the result of being unable to count invisible telogen hairs. When lasing alone, the telogen hairs persist and are counted causing the poorer hair loss result, especially at low anagen:telogen ratios.

The clinical effect of treating areas with high and low anagen number is demonstrated in Figure 5. This individual had pretreatment anagen percentages of 30 and 70%. The low pretreatment anagen site clearly demonstrates less hair loss 9 weeks postoperatively than the high pretreatment anagen site. Statistically significant ($P < 0.01$) improvement in the total hair reduction (Fig. 3a) was found when comparing high vs. low pretreatment anagen:telogen ratio samples.

Individual Follicle Growth Kinetics

Figure 6 shows results from the 13 control-site hairs in which no treatment was performed. It can be seen that the hair cycles were completely asynchronous. The length of anagen and telogen varied from about 10 to 16 weeks.

The effect of the Q-switched Nd:YAG laser on individual follicles can be seen in Figure 7. Treatment was done on six anagen and six telogen hairs. Immediately after treatment of the anagen follicles, a laser-induced telogen was seen lasting from 10–12 weeks. Anagen hairs subsequently were shed within 2–3 weeks of treatment. However, there appeared to be little immediate effect on the telogen follicles, because they continued their telogen cycle unchanged. At the end of telogen, these follicles randomly entered anagen as though they had not been affected by treatment. The range of entry into anagen for all the pretreatment telogen follicles was 8.5 weeks, 3.5–12 weeks after laser treatment. This finding is in contrast to the anagen treated follicles, which re-

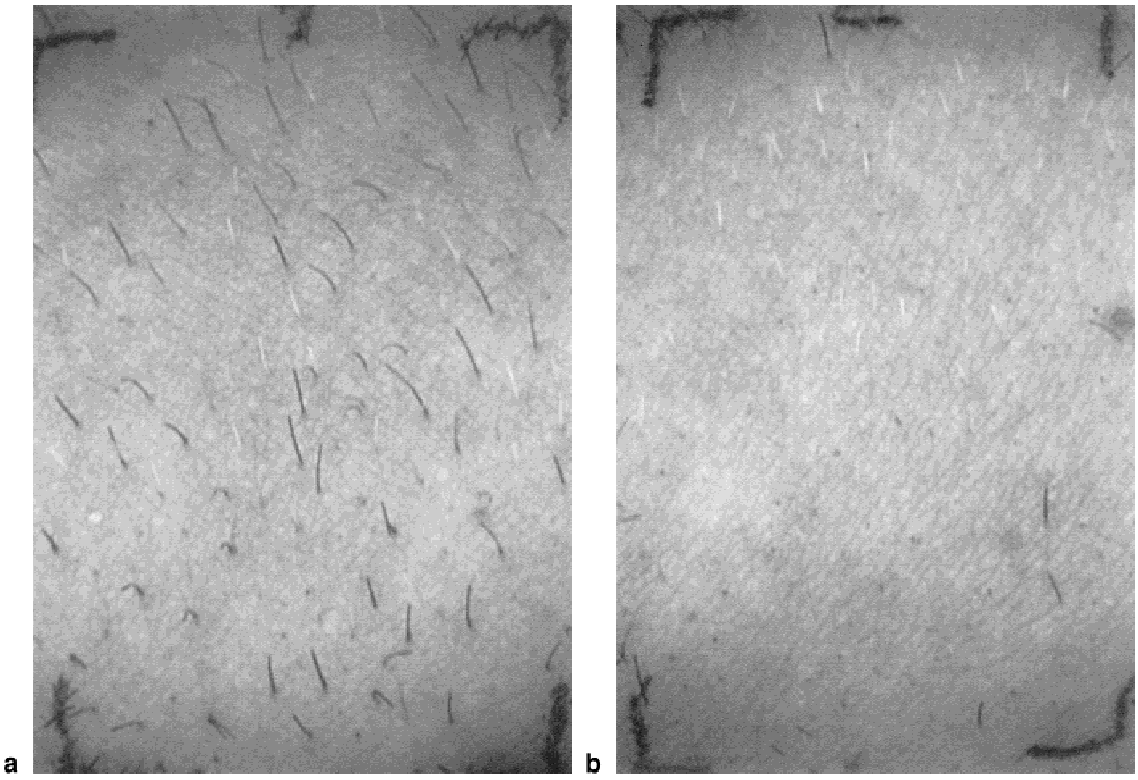

Fig. 5. A typical clinical result 9 weeks after lasing sites with low and high anagen:telogen ratios. The pretreatment anagen:telogen ratios were 30% (**A**) and 70% (**B**).

entered anagen within 2 weeks of one another, 10–12 weeks after treatment.

DISCUSSION

The field of electrology has long incorporated the practice of treating only anagen hairs [5]. Nongrowing hairs apparently demonstrate relatively little response to an electrothermal or electrochemical stimulus. This finding is thought to be because the probe may not reach to the full depth (hair bulb) of the telogen follicle. Therefore, the area to be treated is often shaved several days in advance so that only growing hairs will be visible for treatment.

Laser hair removal articles have stated that only anagen follicles respond to treatment [1–3]. However, there are no human clinical studies that absolutely support this contention. This study was designed to demonstrate the clinical response of human telogen vs. anagen hairs to the Q-switched Nd:YAG laser hair removal process.

In young animals, the demonstration of a laser's effect on anagen and telogen hairs is relatively straightforward. This is largely because of their synchronous hair growth pattern. All body fur synchronously enters anagen, catagen, and subsequently telogen. Shortly after entering the telogen stage, fur from the entire body surface is shed in the process we term molting. Because the hair cycle can be observed grossly and the approximate time periods for each of the stages is known for a given animal, laser treatment can be carried out on hairs in whatever stage is desired. A study such as this has been done in newborn mice by using a 2-ms ruby laser [3]. Some mice were treated when their hair was in the telogen stage and others when in the anagen stage. The results indicated that hairs in telogen were not obviously affected by laser treatment, whereas anagen hairs were significantly damaged.

Such an experiment is not as simple in humans because of the asynchronous nature of human hair. Each individual hair is in its own independent hair cycle stage with what appears to be a complete disregard for its neighbors. Therefore, at any given time or body area, hairs are in each of the different hair cycle stages (Fig. 6). The ratio of the hairs in a given stage, however, remains relatively constant. For instance, in most human body areas, the overall anagen:telogen ratio is about 1:1 at any given time [9].

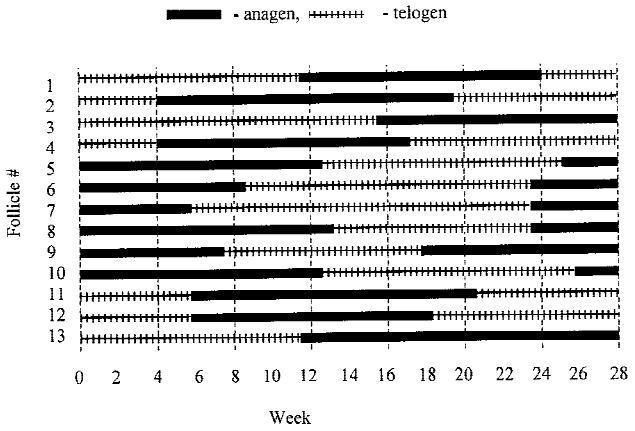

Fig. 6. A graphic representation of hair growth kinetics for 13 control hairs over a 28-week period.

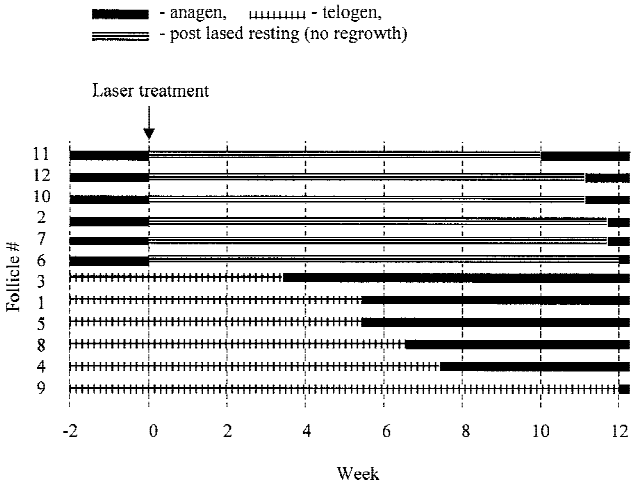

Fig. 7. A graphic representation of hair growth kinetics for hairs treated with the Q-switched Nd:YAG laser.

In previous clinical studies, a marked difference in the human anagen:telogen ratio of nearby areas in the same anatomic region was observed (personal observation, V.G. Kolinko). Finding areas representing the extremes allows the tracking of laser treated areas with comparatively low and high anagen:telogen ratios, approximating what can be more easily done in animals. This study takes advantage of this finding and demonstrates results in four such adjacent areas in 15 subjects.

After Q-switched Nd:YAG laser treatment, areas with high anagen number have a greater decrease in hair density than do those areas with low anagen hair counts. The sites with high anagen number had an average of 1.5–2 times more anagen hairs than the sites with low anagen counts (Fig. 2). Because of this significant difference between the two sites, the disparate effect of treatment becomes clear.

Total hair loss after treatment was less than anagen hair loss (Fig. 3). This should be noted because it gives us information about the effect of laser treatment on telogen hairs. The total hair count reflects the number of anagen plus telogen hairs. The difference between the hair counts in Figure 3a,b is due to telogen hairs, which were present and counted in Figure 3a, but were not counted in Figure 3b. Their presence 4–5 weeks after treatment indicates that the laser had little clinically obvious effect on them.

Figure 4 also demonstrates the lack of apparent telogen response to laser treatment. The vertical bars representing hair counts after laser alone show the same shaped curve as does Figure 3. However, when a test site is treated with laser followed by shaving and hairs are subsequently counted 4–5 weeks later, the hair loss appears to be significantly greater, even at low anagen:telogen ratios. The explanation for this is that, when shaved after treatment, telogen hairs do not grow by the time of the follow-up visit and are, therefore, "invisible" to the eye. As a result, they are not counted and it appears that there are fewer hairs in the shaven than in the unshaven test site, which still has visible telogen hairs that are counted. The difference between the laser-alone sites and those that were lased and shaved is further evidence of the minimal immediate clinical effect lasing has on telogen hairs.

It might be expected that Figure 3b, which considers anagen-only hair loss, would give an identical result to Figure 4, when lasing plus shaving is performed. Both results track the outcome of anagen hairs alone, Figure 3b because only anagen hairs are counted and Figure 4 because only growing anagen hairs can be identified 4–5 weeks after shaving the area. As can be observed, however, the results are different, although significantly so only at the two low anagen:telogen ratios of 0.25 and 0.5. To understand the reason for this difference, the characteristics of low anagen:telogen sites and the two evaluation techniques must be considered.

Inherent differences in low vs. high anagen: telogen ratio samples may partly explain a variance in the results. At low anagen:telogen ratios, there are more telogen follicles than anagen. This preponderance of telogen increases the chances of follicles entering anagen during the follow-up period. If the follicle transitions into anagen during this time, the hair will grow and be counted as anagen. This event can increase the number of

anagen hairs at the 4–5 week follow-up visit, therefore, decreasing the percentage anagen hair loss.

In addition to a tendency for follicles to switch into anagen during the follow-up, another characteristic of low anagen:telogen ratio regions may contribute to the difference in the results. Consistent with the large number of telogen follicles is a small number of anagen in these low anagen:telogen sites. Results derived from these few anagen hairs will be correspondingly more greatly affected by a smaller change in hair count. Therefore, a small increase in anagen hair count will give a relatively large decrease in percentage anagen hair loss.

The above two characteristics of low anagen: telogen ratio sites may affect Figures 3b and 4 results similarly, although the chances for variances increase significantly. In addition, however, innate differences in determining results for these two graphs may also contribute to the dissimilar results. In the case of the technique represented by Figure 3b, the hairs are lased immediately after being trimmed to 1–2 mm so that all hairs are always visible. At the 4–5 week follow-up, anagen hairs are identified as those that have lengthened relative to the other hairs. Figure 4 depicts the 4- to 5-week results after lasing and shaving all hairs flush to the skin surface so that no hairs are visible. At the follow-up visit, only growing anagen hairs can be seen.

Anagen follicles may undergo a telogen conversion after lasing, but the hairs may or may not fall out soon after their conversion. Often, anagen hairs will continue to grow for a week or more before converting into telogen. If they do not fall out by the 4- to 5-week follow-up period in the trimmed technique, they will be counted as anagen because of their growth, thus reducing the anagen hair loss percentage. As pointed out, the presence of any number of adherent telogen-converted anagen hairs will decrease the percentage of anagen hair loss significantly at low anagen:telogen ratios. However, when hairs are shaved flush to the skin surface, these same telogen-converted anagen hairs will not be evident at the 4- to 5- week follow-up even if they do not fall out. The reason for this is that they are converted to nongrowing telogen hairs and will remain flush to the skin surface whether or not they are shed. Even if they grow slightly because of a delayed conversion to telogen and remain adherent, it is difficult to identify short, bleached hairs (note: bleaching of hairs occurs after Q-switched Nd:YAG laser treatment) on follow-up evaluation. Therefore, they will not be counted and the results will appear to be better than the results for the trimmed hairs. Again, the biggest difference in the apparent hair loss between the two graphs will be when there are few anagen hairs at the low anagen:telogen ratios.

In addition to the above, it should be noted that one reason for the inclusion of the lasing and shaving data in Figure 4 is to demonstrate the *perception* of an improved cosmetic result after shaving. Short, bleached hairs are much more difficult to identify than long, bleached hairs; therefore, an apparent improvement in the treatment is observed subjectively. Because of this phenomenon, shaving hairs before or immediately after treatment should improve patient satisfaction with laser hair removal.

It is important to recognize that this study demonstrates an *apparent* lack of telogen follicle response to lasing. However, this "lack of response" should be characterized further for clarification. It is hypothesized that Q-switched lasing often causes a partial, sublethal injury to hair follicles. Anagen hairs can be observed to respond to this injury by essentially shutting down and entering the telogen phase. However, telogen hairs appear to simply remain in telogen after Q-switched laser treatment, so that there is no clinically obvious effect. This finding does not necessarily mean, though, that the laser has had no actual effect on the telogen hair. It is certainly possible that telogen follicles have also undergone a sublethal insult, but merely respond by remaining in telogen. Because there is no change in the hair cycle stage and there is no permanent injury to the telogen hair follicle, it appears that there is no immediate, clinically obvious response of these pilosebaceous units to Q-switched lasing.

Results vary with different laser parameters, so it cannot be stated for certain from the above Q-switched information that longer pulse duration or incoherent instruments would demonstrate the same effect. For instance, follicular injury from nanosecond pulses is mediated by means of a photomechanical effect, whereas millisecond pulses work by photothermally damaging the follicle. The differences in mechanism of action and resulting degree of follicular injury would likely give disparate clinical results. Therefore, this effect should be studied with long pulse (millisecond) hair removal light sources. A study has been presented recently suggesting that a long pulsed ruby and diode laser have the poten-

tial to destroy both anagen and telogen hairs with equivalent probability [10]. Full details of this study are not presently available for further review and comment.

Several possible trends can be seen in the information gathered from the individual follicle study. First, it is evident that untreated hairs have completely asynchronous growth cycles (Fig. 6). This finding has been reported in previous studies and is generally accepted. Next, it appears that hairs can be induced to enter anagen, subsequent to a laser-induced telogen phase, within a very short time period after treatment with the Q-switched Nd:YAG laser. This finding agrees with previously reported data [2,11]. Telogen hairs demonstrate no obvious clinical change after Q-switched lasing.

CONCLUSION

Anagen hairs demonstrate a significantly greater apparent clinical response than do telogen hairs to Q-switched Nd:YAG laser treatment. Therefore, treating body areas when in their highest anagen number should improve clinical results and possibly decrease the treatments necessary for patient satisfaction. Summer treatments, when the anagen:telogen ratio is higher may be an example of this. Other methods to induce anagen before treatment may also improve clinical results.

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